Vol. VII. SEPTEMBER, 1890. No. 5.

AMERICAN METEOROLOGICAL JOURNAL.

A Monthly Review of Meteorology and Medical Climatology.

TABLE OF CONTENTS.

ANN ARBOR, MICH., U. S. A.:

METEOROLOGICAL JOURNAL COMPANY.

19, 21 and 23 Huron Street.

AGENTS: B. Westermann & Co., New York; 2 Thalstrasse, Leipzig; and 189 Boulevard St. Germain, Paris.

Single Copies, 30 cents. Per Annum, $3.00. In European Countries, $3.25.

Entered at the Ann Arbor Postoffice as Second Class Matter.

THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. VII. ANN ARBOR, SEPTEMBER, 1890. NO. 5.

ORIGINAL ARTICLES.

MAGNETIC INSTRUMENTS AND OBSERVATIONS AT THE U. S. NAVAL OBSERVATORY.

BY ENSIGN J. A. HOOGEWERFF, U. S. N., IN CHARGE.
COMMUNICATED BY CAPT. F. V. MCNAIR, U. S. N., SUPERINTENDENT.

In 1887 the Bureau of Navigation erected two buildings on the grounds of the Naval Observatory for magnetic observations and testing compasses.

The building used for absolute observations is of wood, one story in height, 37 feet by 21 feet. In this building are three brick and granite piers set in the magnetic meridian, on the west side of the building. The south pier supports a declinometer, which is a 12 inch bar magnet suspended in a box of brass and glass by a silk suspension 60 inches in length, which is enclosed in a glass tube provided with a torsion circle at the top.

On the middle pier is a large theodolite which is directed on a small plane mirror on the north end of the declinometer, and the reflection of the division of a scale under the theodolite, which is crossed by the thread, can be read off.

From these instruments the absolute declination is determined by the method of Gauss.

The north pier has a stand on it for holding compasses, which may be tested by means of the theodolite, declinometer, and magnets for deflection, for accuracy in the position and graduation of the card, for sensitiveness, and for directive force.

There are besides, two heavy wooden piers in this building, well removed from the declinometer, on one of which is a magnetometer by Elliott Bros., and on the other a dip circle.

The second building, which is 50 feet south of the first, consists of an underground cell with a small wooden building over it. The cell is of brick with a cement floor, and has within it an inner cell of double thickness of wood. Great care was taken in building to drain the ground thoroughly and to exclude all magnetic material. This cell is entered from the room above. In it is set up on granite piers a set of Kew magnetographs, comprising a declination, a horizontal force, and a vertical force instrument. The clock which runs the cylinders on which the sensitive paper is placed shuts the light from the cylinders automatically at every even hour for about two minutes. There are telescopes and scales for eye readings which can be taken at any time. The room above the cellar has a dark room attached for developing the papers.

In both buildings great care was taken to exclude all iron, they being put together with wood and copper. The stoves for heating the buildings are of soapstone with copper pipes.

Two seismoscopes connected with clocks kept rated, and a seismograph are kept in working order.

Absolute observations for declination are made twice each day, which, applied to the declination traces, furnish two values for each day's base line. On two days in succession, at intervals of two weeks, absolute observations of horizontal intensity are made with the Kew magnetometer, and an observation for dip is taken immediately before and immediately after each such observation.

Whenever absolute observations are taken eye readings are made of the magnetographs, and the results of these readings compared with those given by the photographs. Observations are made at least every three months to determine all constants and corrections for instruments as far as possible, such as for azimuth mark and collimation of theodolite, correction to large declinometer for reversal, etc., and for moment of inertia of vibrating magnet and suspension used in making observations of horizontal intensity.

Observations for determining temperature co-efficients and value in scale divisions of change in force for horizontal and vertical force magnetographs are made frequently.

The photographic traces of declination, horizontal and ver-

tical force are measured and recorded for each hour, and these measurements are combined with the absolute observations, so that all results are finally expressed in absolute measure, the C. G. S. unit of force being used.

The declination traces for each month are combined in a composite curve from which the mean value of the declination freed from disturbances is obtained.

For two years the declination traces taken here, and at Toronto and Los Angeles, have been compared graphically on all disturbed days, and the traces at Pawlosk for 1889 have been received, and will be compared with those of the three places mentioned.

Blue print copies of the composite curves of declination and of the comparisons of disturbed days of declination have been furnished persons and observatories expressing a desire for them.

As yet none of the work has been published, but the reductions of the observations for 1889 are nearly ready, and it is hoped that they will be published this year.

ESPY'S EXPERIMENTS ON STORM GENERATION.

By Professor H. A. Hazen.

It has been a matter of great surprise to the present writer, that the only experiments that have ever been made regarding the liberation of latent heat on cloud formation were made more than fifty years ago and have never been checked. Foreign writers, notably Reye, have accepted Espy's work without question. It is entirely safe to say, that the sum and substance of all modern theories regarding storm formation take their rise in this work of Espy between 1838 and 1841. The profoundest calculations and speculations upon the development of energy in the free air are based upon a few experiments of the crudest sort made in a small jar. No other science, except Meteorology, have ever been content with such results. It has seemed of the utmost importance to give Espy's work a most thorough review, and to repeat, if possible, his methods. More than a year has elapsed since this study was begun, but has been only quite recently that the seeming contradictions between his experiments and the modern researches have been almost entirely cleared up, and the various results united in one harmoni-

ous whole. Prof. Espy's work will be found largely in his "Philosophy of Storms" published in 1841, and while he repeated his experiments with much more complicated apparatus later, yet the results did not differ materially from those first obtained.

Nepheloscope. The apparatus he used was called a *cloud-examiner.* It consisted of a gallon jar having a tube at the top with a stop cock which could prevent the escape of the air after it had been compressed by a syringe. There was also a mercury gauge which communicated with the interior and by which the amount of compression on the inside air could be accurately measured. In the first experiments the syringe was not used, but the jar was taken, first into a cold place, and when the air was cooled down, the stop cock was turned and the jar taken to a warm place. The heat expanded the air and the amount was measured by the gauge. The same was done in the opposite direction, that is, the jar was taken from a warm to a cool place; in this case the gauge indicated a partial vacuum in the jar. Experiments were tried with moist and dry air. There was one very important point brought out by these preliminary trials which was not noticed by Espy. The average change in the gauge for each degree of heat applied or subtracted was .059 inch. Assuming the barometer reading as 29.″8 we see that this indicates that the pressure would have been doubled by a rise of 505°, which agrees remarkably with the 490° determined by most careful researches since Espy's day. This is an important point, because we can now tell exactly how much heat ought to be produced in our experiments, that is, if we compress our air 10 we ought to raise its temperature 163°, provided no heat is lost in the operation.

At first sight this result seems incredible and we can hardly believe it correct, but it should be noticed that the heat required to warm up air is very slight; for example, it has been computed that the heat required to evaporate a single grain of water would raise a cubic foot of air 7° in temperature. In order to duplicate as near as possible Espy's work, a jar was obtained, and in addition to the syringe for compressing the air, there was used a very delicate thermometer for measuring its temperature. This instrument had a bulb .06″ in diameter and 1.″ long, and would change a degree in two or three seconds. By compressing the air at different rates of speed the final temperature was found nearly the same under all conditions. This would seem to show little or no effect from lagging in the thermometer. For

example, compressing to 10″, or one-third atmosphere, the temperature was increased 7°; allowing 1° for lagging, we have 8° as the increase in the centre, and as the temperature near the jar was that of the air, we may say that the average increase for the whole jar was not far from 4°. On suddenly expanding the air, the cooling was found very nearly 7°, or the same as the previous heating. This seems a very remarkable result. It cannot be supposed for a moment that the amount of work done in driving away the air at the mouth of the jar is equal to that required for compressing the air, and yet this is just what we are taught. I leave the explanation of this fact to others.

In one of Espy's experiments the air was compressed to 10″ and the rise in the gauge after explosion was 2″.15, this would indicate a cooling of 36° provided the whole of the rise in the gauge was due to a heating of the air from outside. This is nine times as great as that found with the thermometer under like conditions. In seeking for an explanation of this anomaly, it was very quickly found that a delay of only a few seconds in arresting the expansion, after the mercury in the gauge had become level, resulted in obliterating nearly all the rise supposed to be due to heat from outside. Espy himself emphasizes the necessity of arresting the expansion at the moment the mercury became level, or as he thought at the moment the greatest cooling had occurred. Professor Marvin has suggested that the mercury in the gauge would have a momentum and hence would come to a level before the air reached an equilibrium with that outside. In order to test this, the air was compressed 400mm in ten seconds and expanded at different rates of speed, in five, ten and twenty seconds, the expansion being arrested in each case at just the moment the mercury in the gauge became level. The rise of the mercury in these cases was 41, 21 and 12 millimeters respectively. In another instance the expansion was arrested after about 4″ of air had escaped and before there was any cooling due to expansion; here also there was a marked rise in the gauge. The evidence is all one way and points to the fact that temperature had little or nothing to do with the rise in the gauge after expansion as thought by Espy. This is a most astonishing fact and gives the death blow to Espy's theory, founded on these experiments, that there can be any liberation of latent heat on the condensation of moisture in the atmosphere. The varying results found by Espy in expanding moist and dry air could no doubt be easily explained if we knew all

the facts in the case. Possibly the whirls in the air in the jar were slightly different in the two cases.

We can arrive at precisely the same conclusion as the above from a study of the effects produced in the jar. Even if latent heat were liberated on the formation of cloud, yet, as this cloud disappears very quickly, we must suppose that the heat has been used in evaporating that and cannot be employed in expanding the air. Under ordinary circumstances no precipitation reaches the bottom of the jar. Whatever may be the explanation of Espy's results, there can be no doubt at all as to the effect on a thermometer in expanding moist and dry air. This experiment was tried scores of times and the result showed no difference between the cooling except that the dry air cooled a very little more than the moist. Espy found that by compressing his moist air and then waiting several days before expanding it, its behavior was the same as that of dry air. This led him to conclude that such a delay would serve to unsaturate the air, but this cannot be admitted. The natural effect of such a compression as he used would be to render the air less saturated than before, and if the compressed air were allowed to rest in contact with water several days, there can be little doubt but that it would gradually approach saturation. Espy does not inform us as to the formation of cloud in these later experiments, but we may conclude that there must have been one.

There is also an interesting question regarding the state of the moist air used by Espy. He thought that he could saturate the air by leaving a little water in the bottom of the jar, but it is certain that this would not produce the desired effect. It has been found that forcing air to bubble through several inches of water does not saturate it and the only feasible plan was to force it through wet sponge. This breaks up the bubbles and brings the air within one per cent. of saturation. As Espy pumped in the outside air he must have had it full of dust and it is known that in dusty air a cloud can be formed when it is far from moist. For example, in the number of this Journal for September, 1889, experiments were given showing a cloud in dry air, or at least having only two per cent. of moisture. Whatever may have been the state of this earlier moist air, there can be no question but that the later results were had with saturated air and these show clearly the correspondence between the effects of expansion in moist and dry air. Moreover, in these later results the lagging of the thermometer did not enter in

any wise for it would be precisely the same in both moist and dry air.

These conclusions have been reached only after the most deliberate study and after finding that the later experiments seemed to fit into and to explain the earlier in all parts. It is hardly to be expected that those who have laid great store by Espy's work can be easily convinced by these arguments. It is much to be hoped that others will consider this question most seriously and that we may have a substantial agreement as to what Espy's work really shows, and more than all, as to what help laboratory experiments can give us in elucidating the complex phenomena of the atmosphere. Professor Wild, of St. Petersburg, has truly said: "Without exact and satisfactory data Meteorology cannot develop as a science, but will be, as heretofore, mainly a tumbling ground for vague speculations and dilettante investigations."

ORIGIN OF STORMS.

By E. B. Garriott.

Storms are incubated by heat and nourished by moisture; heat is necessary to their birth, and moisture is essential to their continuation, growth, and intensity. The condition favorable to their development is, a stratum of cold air overlying a stratum or body of warm air. As a body of warm air, represented by a hot air balloon, strives to rise through and above the surrounding colder and heavier air, so does a body of warm air pent up beneath a stratum of colder air seek to ascend. The conditions thus presented would probably undergo gradual changes, unmarked by visible atmospheric disturbances, were the respective bodies of air in a state of quietude; but with the constant general movements of the atmosphere, in the form of air currents and winds, the density or thickness of the envelope of cold air becomes less, in places, and the upward pressure of the warm air, which it may be assumed is constantly receiving an accretion of heat from the original source, *i. e.*, radiation of heat from the earth's surface, causes a vent through which the closely pent up warm air issues. Thus the first stage of a storm's development is presented.

General or principal storms can only develop where an excess of heat is received from the earth's surface by radiation. Thus,

storms of continental origin develop in the lee of the more elevated mountain ranges, where the cold air from the mountains flows over a considerable extent of almost, if not entirely, arid country, which has become heated by the sun's rays. Secondary or local disturbances occur within the area of general storms, at points where bodies of warm air are drawn under colder air currents or strata by the cyclonic circulation of winds, and research has not at the present time defined whether electricity, which constitutes a prominent feature of local storms, is in the nature of a cause or an effect of the intensified conditions which characterize these storms.

While during their incubation general storms depend upon ascending currents of warm air, it is evident that this element, alone, would afford sustenance only while they remained central over the region of hot air supply, and while there was an excessive quantity of ascending hot surface air. The ascent of the warm air is, however, attended by a diminution of atmospheric pressure at the earth's surface which causes an inflow of surface air towards the point. When the influence of the depression is not extended beyond the region of dry air, and vapor-laden air from more distant regions is not drawn in, the barometric depression generally remains stationary, and forms what is termed a permanent area of low pressure; such areas are found over the sheltered, arid regions of the continents during the warm months. When, however, storms receive an accretion of strength in the form of moist air, drawn in by the cyclonic circulation of winds, they assume increased intensity proportional to the supply of heat and moisture, and also assume a progressive movement. As moist air cools more slowly than dry air, and a portion of the heat liberated by the condensation of aqueous vapor in the ascending air by the cold of elevation is absorbed by, and expands, the surrounding air, the ascending current of warm, moist air rises into and through the great mass of the surrounding colder atmosphere, and there is thus presented at a considerable elevation, a mass or column of warm, moist air whose aqueous vapor is being precipitated by the coldness of the atmosphere by which it is surrounded, and into which there is a constant flow of warm, vapor-laden air from the earth's surface. This is the seat of the storm's power.

The direction of the progressive movement of general storms, while, as a rule, corresponding with the general drift of the atmosphere over the region where the storms exist, is modified

or changed by several conditions, the more important of which are atmospheric pressure, temperature, and moisture. As heat and moisture are the life and food of storms, it may safely be assumed that cold, dry air, being deficient in the essential properties of storms, would tend to weaken or dissipate them. In practice it is found that areas of high pressure, which are made up of colder, dry air, are antagonistic to low pressure storms, and that there is a disposition on the part of low pressure storms to avoid them, while they, in turn, are but little affected by the movements of areas of low pressure. Areas of high pressure represent huge atmospheric waves which sweep eastward over the earth's surface; in the middle latitudes they originate in the colder regions of the north, and settle to the southward where less resistance is offered by the warmer, lighter air of the lower-middle latitudes. The areas of low pressure in endeavoring to advance eastward seem to avoid the heavier bodies of cold, dry air, and move towards the point where there is the least resistance to their advance, which would naturally be towards warm, moist regions, and it is safe to assume that areas of low pressure will, as a rule, advance towards the region of greatest moisture or of heaviest precipitation within their influence, which represents the region of greatest heat, although this feature may not be apparent at the earth's surface, and that cold air in their advance will retard or deflect their course.

A verification of the facts presented will be found in a study of the storms of the North American continent, a large majority of which originate over the great plateau region in the lee of the elevated Pacific coast ranges of mountains. This region receives but little rainfall and is composed largely of what is termed arid land; the overlying atmosphere becomes excessively warm by the radiation of heat from the earth's surface, and the thermometer registers temperatures far above those reached at extreme southern points in the United States east of the Mississippi River. The prevailing westerly winds in passing over the mountain ranges are cooled by elevation, and moisture contained therein is precipitated on the windward side of the mountains. When, by the radiation of an unusual quantity of heat, there is a large accumulation of warm air over a part of this region, the conditions are favorable to the development of storms in the manner herein defined. If the initiatory upward movement of the warm air is so pronounced as to cause a depression of sufficient power to draw in air from the moist

regions east of the Rocky Mountains, the storm rapidly augments in energy. A study of these storms shows that, as a rule, they advance to the regions of greatest moisture, or humidity, which regions embrace the Great Lakes and the Gulf of Mexico, and secondarily the valleys of the principal rivers, and it will be seen that storms which originate north of the latitude of the Great Lakes move south of east, and those of the middle latitudes east or north of east, the storm-tracks converging towards the Great Lakes and the Saint Lawrence valley. It will also be observed that storms which originate over the southern part of the plateau region have a tendency to move towards the Gulf of Mexico, which impulse is in a majority of instances overcome by the influence of the earth's rotation, the prevailing winds, and the moist region of the Mississippi valley, towards and over which they generally move. With areas of pressure north or northeast of low pressure storms the latter will, as a rule, be held back or deflected in their course until the area of high pressure, which opposes not only cold but dry air, advances on its course. In exceptional cases, only, do low pressure storms develop sufficient strength to pass through or scatter areas of high pressure. The common destination of areas of high pressure which move over the United States is the mid-Atlantic Ocean over and south of the Azores. When low or comparatively low pressure exists over that region, with the advance of an area of high pressure over the American continent, the latter moves rapidly to mid-ocean, and on the contrary, when the pressure is high over and near the Azores, the area of high pressure from the west adds to and extends the limits of the mid-Atlantic area of high pressure westward. In the one case low pressure storms advance east-northeast from the coast without opposition, and in the other they are crowded back on the coast or over the eastern states, or dissipate. On account, however, of the large supply of moisture available, when storms reach the eastern coast of the United States they are seldom dissipated by high pressure to the eastward, and it is a notable fact that the severest storms of the Atlantic coast states occur when areas of low pressure have been crowded back by high pressure to the eastward and northeastward.

The science of weather predicting requires not only an intimate knowledge of the laws governing a storm's development and probable subsequent history, but also the intuitive foresight of the effects of visible meteorological causes and conditions.

TORNADOES IN KENTUCKY AND TENNESSEE.

STATE TORNADO CHARTS.—KENTUCKY.

BY LIEUT. JNO. P. FINLEY, SIGNAL SERVICE, U. S. A.

TABLE I.—*Tornadoes in Kentucky.*

Period of observation, 79 years, 1810-1888.
Total number of storms,—46.
Year of greatest frequency, 1884,—7 storms.
Average yearly frequency,—2 storms.
Years in past ten (10) years, no report of storms,—1881 and 1882.
Months of greatest frequency, February and June,—7 storms each.
Days of greatest frequency, February 19 and March 25,—4 storms each.
Hour of greatest frequency, 3 to 4 P. M.
Month without storms, September.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, north-northeast portion.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Kentucky for a period of 79 years, from 1810 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Rockcastle and Jackson	....	1810	....	E 30° N.	....	....
Bath	June —.	1840	....	E.	....	....
Fayette	August 20.	1840	11:30 p. m.	E 10° N.	....	3,960.
Hickman	May 13.	1854	Afternoon.	ENE.	Funnel.	Narrow.
Jefferson	August 27.	1854	....	....	....	....
Montgomery	June —.	1855	2 p. m.	E.	....	....
Montgomery	July —.	1856	4 p. m.	NE.	....	....
Hickman	July 15.	1856	Afternoon.	NE.	Funnel.	Narrow.
Hickman	April 13.	1859	"	NE.	"	"
McCracken	June 30.	1863	p. m.	....	....	....
Spencer	....	1866	....	NE.	....	660.
Barren	June 17.	1870	4 a. m.	NE.	Funnel.	1,320 to 2,640.
Laurel and Jackson	....	1873	....	E 30° N.	....	....
Fulton	December 10.	1873	....	....	....	....
Hickman	December 26.	1875	Afternoon.	NE.	....	Narrow.
Muhlenberg	"	1875	3:40 p. m.	NE.	....	100 to 200.
Hickman	April 20.	1876	Afternoon.	NE.	Funnel.	Narrow.
Madison	July 1.	1877	....	....	....	....
Casey	March 2.	1878	Bet. 2 and 3 p. m.	NE.	....	1,200.
Marshall	July 23.	1879	Afternoon.	....	....	....
Jefferson	November 28.	1879	5:45 a. m.	NE.	Dark whir'g mass.	....
Lincoln	February 12.	1880	....	....	....	....
Bourbon	October 29.	1883	5 a. m.	E.	....	Few yards.
Christian	May 14.	1883	6 p. m.	E.	....	....
Bourbon	August 10.	1883	4 p. m.	E.	....	....
Hickman	January 15.	1884	Afternoon.	ENE.	Funnel.	300.
Nelson and Shelby	February 19.	1884	2 p. m.	NE.	Cone.	825.
Bourbon	"	1884	6:20 p. m.	NE.	....	....
Fayette	March 11.	1884	4 p. m.	NNE.	....	....
Jackson	March 25.	1884	....	NE.	Funnel.	....
Jackson	"	1884	4 p. m.	NE.	....	450 to 600.
Laurel and Clay	"	1884	"	....	Funnel.	2,640.
Harrison and Bracken	"	1884	4:45 p. m.	E 10° N.	"	750 to 3,960.
Boyle	June 7.	1885	3 p. m.	NE.	"	2,400.
Hopkins	November 6.	1885	4 p. m.	....	....	2,640.
Nelson	May 13.	1886	9 p. m.	NE.	Funnel.	1,320.
Franklin	"	1886	3:30 a. m.	NE.	"	2,640.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Jefferson	July 8.	1886	6 p. m.	E.	Funnel.	....
Bracken	February 11.	1887	"	NE.	"	2,640.
Spencer	February 26.	1887	9 a m.	NE.	"	Narrow.
Bourbon	April 22.	1887	8 a. m.	S 53° E.	"	900 to 1,200.
Clark	April 28.	1887	Evening.	SE.	"	Narrow.
Ohio	February 19.	1888	"	NE.	....	2,640.
Hickman	"	1888	Afternoon.	NE.	Funnel.	Narrow.
Todd	June 27.	1888	Evening.	SE.	"	1,320.
Muhlenberg	"	1888	"	SE.	"	1,320.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Kentucky.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	15	1	1
February	11, 12, (19)^{4} and 26	4	7
March	2, 11 and (25)^{4}	3	6
April	13, 20, 22 and 28	4	4
May	(13)^{3} and 14	2	4
June	7, 17, (27)^{2}, 30 and (—)^{2}	5	7
July	1, 8, 15, 23 and (—)	5	5
August	10, 20 and 27	3	3
October	29	1	1
November	6 and 28	2	2
December	10 and (26)^{2}	2	3
(—) Blank	(—)^{3}	3	3
Total	....	35	46

NOTE.—The (—) signifies date missing

STATE TORNADO CHARTS.—TENNESSEE.*

By LIEUT. JNO. P. FINLEY, SIGNAL SERVICE, U. S. A.

TABLE I.—*Tornadoes in Tennessee.*

Period of observation, 81 years,—1808-1888.

Total number of storms,—41.

Year of greatest frequency, 1880,—7 storms.

Average yearly frequency,—2.2 storms.

Years in past ten (10) years, no report of storms, 1882, 1883 and 1886.

Month of greatest frequency, April,—12 storms.

Day of greatest frequency, April 18th,—3 storms.

Hours of greatest frequency,—6 to 7 P. M. and 7 to 8 P. M.

Months without storms,—September and October.

Prevailing direction of storm movement,—NE.

Region of maximum storm frequency,—central and extreme western portions.

---

* For Chart, see page 251.

TABLE II.—*A Chronological Table showing the location, date and time of occurrence and general character of formation and movement of Tornadoes in the State of Tennessee, for a period of 81 years, from 1808 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Knox	May 24.	1808	2 p. m.			
Maury	March 30.	1830		NE.		
Dickson	May 31.	1830	Evening.	NE.		
Bedford	"	1830	Midnight.	E.	Funnel.	800 to 1,200.
Obion	April —.	1833				
Obion	"	1834				
Obion	"	1843				1,320.
Robertson	August 8.	1857	2 p. m.			
Washington	June —.	1861		E.		
Benton and McNairy	February 9.	1871				
Hamilton	April 18.	1871	7:30 p. m.	E.		1,320 to 2,640.
Obion	December 10.	1873				
Obion	May 17.	1874	7:30 p. m.	NW. ?		300.
Shelby	March 15.	1875	Afternoon.			
Knox	March 20.	1875				
Lawrence, Ruthford and Sumner	April 18.	1877	11 p. m.	NE.		1,320.
Shelby	June 17.	1877	7 p. m.	NE.	Funnel.	600.
Wilson	August 29.	1877	3:30 p. m.		"	400.
Hardeman	April 14.	1879	Afternoon.	NE.		800 to 1,200.
Hardeman	"	1879	9 p. m.	NE.		1,000.
Williamson	January 22.	1880				
Davidson	February 12.	1880	10 p. m.	NE.	Funnel.	2,500.
Coffee	"	1880	10:30 p. m.		"	
Overton	April 3.	1880			Balloon.	3,960 to 5,280.
Giles	April 25.	1880				
Cumberland	"	1880	7:30 p. m.	NE.	Funnel.	
Sullivan	June 29.	1880	Afternoon.	NE.	"	
Montgomery	April 28.	1881		NE.		
Maury	July 30.	1884	5:30 p. m.		Funnel.	2,640.
Gibson	August 29.	1884	7 p. m.	NE.	"	
Franklin, Coffee and Warren	November 6.	1885	2 p. m.	N 40° E.	"	150 to 600.
Marshall	January 13.	1887	6 p. m.	NE.	"	1,320.
Robertson	"	1887	"	E.	"	1,320 to 2,640.
Maury	March 27.	1887	4:30 p. m.	NE.	"	90.
Hamilton	April 18.	1887	4:30 a. m.	NE.	"	Narrow.
Greene	June 1.	1887	Evening.	NE.		450.
Fayette	August 3.	1887	"	Easterly.		2,640.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Robertson	February 24.	1888	....	NE.	Funnel.	150.
London	March 20.	1888	10 p. m.	NE.	"	1,320 to 5,280.
Dickens	August 20.	1888	Evening.	Easterly.	....	1,320.
Montgomery	December 16.	1888	7 p. m.	NE.	Funnel.	100.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Tennessee.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	$(13)^2$ and 22	2	3
February	9, $(12)^2$ and 24	3	4
March	15, $(20)^2$, 27 and 30	4	5
April	3, $(14)^2$, $(18)^3$, $(25)^2$, 28 and $(—)^3$	6	12
May	17, 24 and $(31)^2$	3	4
June	1, 17, 29 and (—)	4	4
July	30	1	1
August	3, 8, 20 and $(29)^2$	4	5
November	6	1	1
December	10 and 16	2	2
Total		30	41

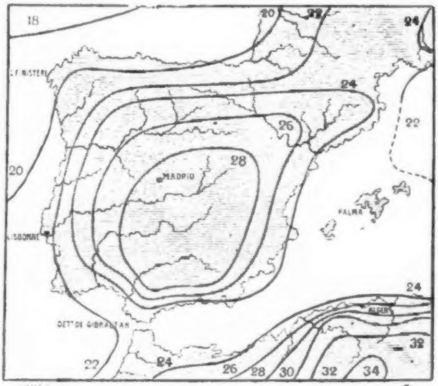
NOTE.—The blank (—) signifies date missing.

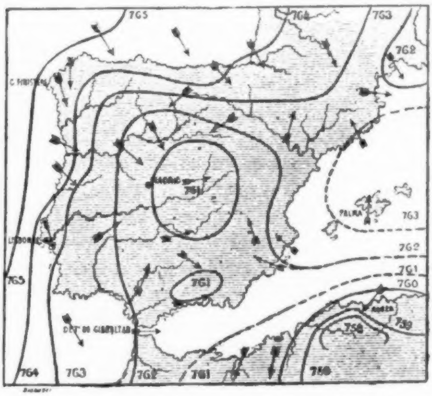
SUPPLEMENTARY ARTICLE. FIGURES RELATING TO TROMBES AND TORNADOES.

By H. Faye,
Membre de l'Institut, Président du Bureau des Longitudes, etc.

Since the appearance of the first two articles of this series, I have regretted not having given more space to figures; of these I now offer two series.

First Series, First Article.—These two figures relate to page 497 of the March (1890) number of the Journal. The first figure represents the isotherms of July upon a given day, in Spain. The second represents the isobars and centripetal winds for the same time and in the same country.





It is a question of the static "low." There are two analogous figures for January lacking, that is to say, the isotherms in Spain for the month of January, and a static "high," or anticyclone, for the same date. They may be found in M. Sprung's "Meteorologie," page 311.

Second Series, Second Article.—The first four figures relate to the natural phenomena which are often cited to prove that *trombes* and tornadoes, and even cyclones, are columns of

ascending air, which exercise below a sort of suction or aspiration.

The two following relate to the attempts which have been made to produce ascending *trombes* experimentally.

The three last are the figures typical of three theories: that of the first meteorologists, that of meteorologists of the present time (Ferrel), and that which I have myself proposed.

Natural Phenomena.—In the first place there are the whirls of flame and smoke, which form in a conflagration, that of a forest, for example; this figure is borrowed from the work

FIGURE 1.

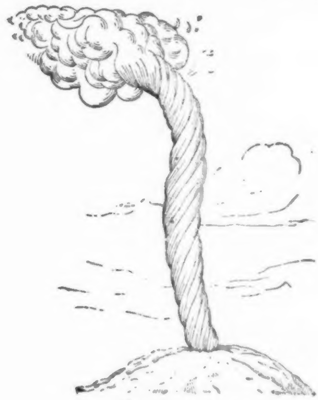


FIGURE 2.

of M. Th. Reye, "Die Wirbelstürme, Tornados, und Wettersäulen," Plate I. (Figure 1).

Then we have the whirling volumes of vapor and cinders which rise above a volcano in a state of more or less marked activity. Same volume, page 11. (Figure 2).

Figure 3 represents dried wisps of grass which sometimes rise in a light spiral above a stack of hay newly cut, in which, by the action of the sun, an active fermentation has taken place, causing the release of gases which are extremely warm (sometimes to the point of incandescence). The column of hay should be a few twisted blades.

Then last come the columns of dust, observed by M. Raoul Pictet, in the desert, near Cairo, upon the summit of a sandy hill, in calm weather under a hot sun. In this cut the column is too dark. (Figure 4).

These gyratory phenomena, weak and indecisive as they are,

necessarily remain stationary if the weather is calm; if otherwise, they are moved about at the mercy of the wind, like the columns of smoke which rise from our chimneys. They have

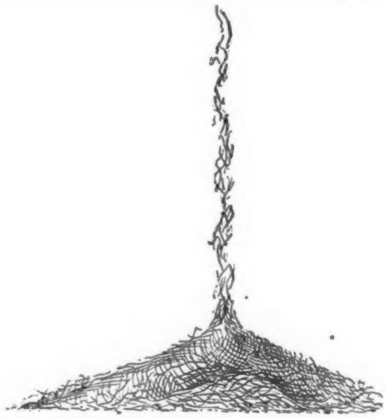


FIGURE 3.

FIGURE 4.

not the slightest relation to *trombes*, tornadoes, typhoons or cyclones, all of which move with great velocity upon definite trajectories.

Artificial Whirls.—The attempt has often been made to imitate trombes by using a whirling machine in a reservoir of water. The following figure represents the experiment of M. Colladon, of Geneva: (Figure 5).

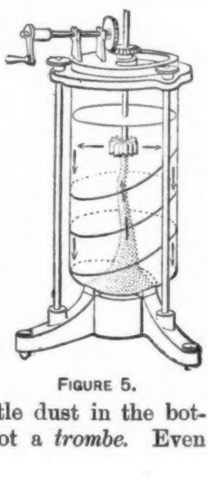


FIGURE 5.

The vanes of the whirler with a vertical axis drive the water horizontally toward the walls of the reservoir, and thus produce an aspiration below the little apparatus, as in all the aspirators with centrifugal force. The water sent horizontally descends in part the length of the walls of the cylindrical reservoir while turning a little, and goes to the bottom to rejoin that which obeys the aspiring action of the whirler. From this arises an ascending column which is made visible by a little dust in the bottom of the reservoir. This is evidently not a *trombe.* Even the external resemblance is wanting.

Then we have the experiment of M. Wyher, who operates on free air with a ventilator with vanes one inch in diameter, making 1,200 or 1,500 revolutions in a minute (Figure 6).

The author suppressed the cylindrical reservoir of his predecessor, and in doing so suppresses the descending movement of the fluid the length of the walls. But as the vanes of his ventilator are attached to the walls of a cylindrical box, open only below, this descending movement in the surrounding air must be renewed on a larger scale. The air driven by the vanes is forced, in effect, by the lateral wall of the box of the whirler to descend, while turning and separating from the axis. At contact with a nappe of water placed below and making an obstacle, a part of this air is reflected and goes to join the column aspired upwards by the ventilator. This air rises and imparts to the aspired air an ascending spiral movement, counteracted a little higher up by the descending spiral movement of the general mass. There is thus produced, near the axis, a slender ascending column, without a pronounced gyration, which is displaced at the least movement of the air of the room where the experiments are made. It is made visible by placing warm water in the reservoir so as to produce a little vapor.

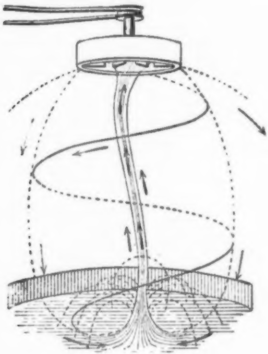


FIGURE 6.

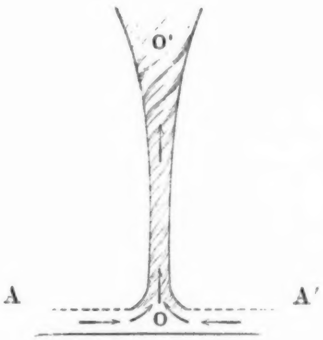


FIGURE 7.

It is necessary to caution the reader against a false effect in the cut which the engraver would have had to take great pains to avoid. It appears in the figure as if this slender column were filled with ascending water. It contains only air and a little vapor in the form of mist; the water of the reservoir is

scarcely raised by the air which ascends after having traversed its surface.

This curious phenomenon is accompanied at the foot of the slender central column of mist by a lateral projection of fine droplets carried along by the ascending air; it has been thought that the reproduction of the *buisson* of a water-spout may be seen there. It shows how complicated are the regular movements which may be artificially produced in a mass of air by the aid of a whirler turning with great velocity, but there is nothing there which resembles, the least in world, a *trombe* or a tornado.

I would say the same of the experiments of Dr. Wettin, of which the details may be found in Dr. Sprung's "Meteorologie." The author tried to reproduce the effect which was attributed a few years ago to the rotation of the terrestrial globe, in determining in *trombes* or tornadoes the terrible gyration by which they are animated. He obtained no appreciable effect except in communicating to the horizontal bottom of his apparatus a velocity of rotation 80,000 or 100,000 times greater than that of the earth.

Theoretical Figure Proposed for Tornadoes.—Meteorologists were first inspired with distrust by the idea which teaches that *trombes* and tornadoes pump water from the sea, and carry all sorts of small objects in their ascending gyrations. They correspond perfectly to the first four figures, in which we saw successively smoke, volcanic ashes, the debris of hay and of dust, ascend while turning in the air.

In Figure 7 (page 260), AA' is a stratum of calm air in contact with the ground, warmed by the sun's rays. O is the opening, accidentally made (by a falling leaf or a flying bird), in the surface of separation of the two media. OO' is a column of air which rises through this orifice; it is fed by the warm air of the stratum AA', of which the humidity favors and prolongs the ascension, especially if the instability of the lower atmospheric strata is repeated in the upper regions.

Two things are lacking in this conception, the gyration and the movement of translation upon a trajectory, geometrically determined. The effort has been made to introduce into it the effect that the slow diurnal rotation of the earth ought to produce upon these centripetal currents, with the view of obtaining a gyration, but no one has even tried to introduce a translation. We cannot approve here the opinion of the meteorologists who

believe that the upper currents of the atmosphere blowing on the top of this ascending column produced at the level of the ground in calm air, are going to carry it entire in their direction and make it travel from equator to pole. Such is, however, the foundation of the actual theory of cyclones. But as it is evident that tornadoes originate above, and not below, and descend from the clouds instead of rising to them, the theory has been modified, in so far as it concerned them, while preserving it with reference to cyclones. Hence the theory of Mr. Ferrel. It transports the origin of the gyrations of a tornado to the horizontal currents which carry the clouds immediately above our heads.

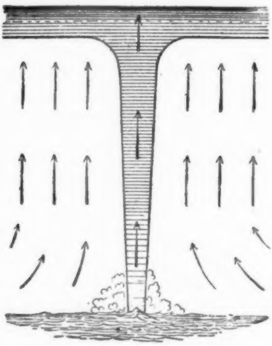


FIGURE 8.

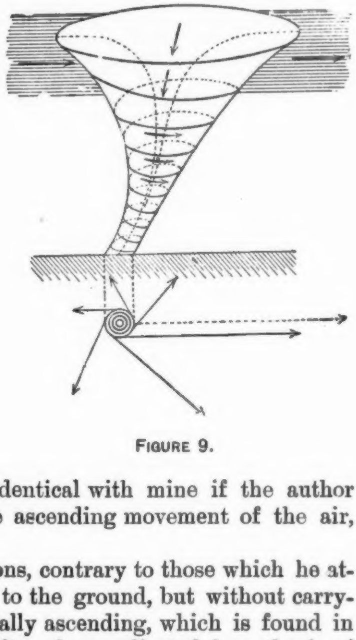


FIGURE 9.

This conception would be identical with mine if the author had not held especially to the ascending movement of the air, as may be seen in Figure 8.

He admits that the gyrations, contrary to those which he attributes to cyclones, descend to the ground, but without carrying downwards the air essentially ascending, which is found in their spirals. It is a difficult and complicated hypothesis of which this figure does not give a clear idea. It is nevertheless a great step towards what I believe to be the truth.

Finally, I give the figure of a tornado as I conceive it to be. (Figure 9.) It is in the upper part a vertical cup, or rather the projection of a tornado upon a vertical plane I have tried to

mark upon it the horizontal current in which the gyrations originate. The lower part shows on the ground the foot of the tornado, imparting violent impulsions to the obstacles which it encounters. Doubtless it seems at first sight difficult to understand that simple inequalities of velocity in a current determine a great gyration, and that this gyration is descending. I even admit that the explanations, which I gave of this fact in the first paper, are not of a nature to satisfy the mind. But descending whirls of water-courses offered us a manifest experiment in confirmation, and it has been admitted even by Mr. Ferrel, and numerous meteorologists who follow the development of his ideas, that the gyrations engendered above can be propagated downwards.

It will be seen in the third paper that tornadoes are not alone the occasion of descending gyrations. They occur in all the magnificent phenomena which constitute Dynamic Meteorology.

FORESTS AND SOIL TEMPERATURES.

By M. W. Harrington.

1. The temperature of forest-soils, compared with that of the soil of adjacent open ground, affords a better measure of the forest effect than does the temperature of the constantly mixed and moving air. Moreover, the rapid daily and non-periodic changes of temperature of the air penetrate but slightly, and with diminished range, into the soil, so that the temperatures of the latter show the mean effect of the forest with a shorter series of observations than do the temperatures of the air. The problem is also of theoretical interest:—we have applied at adjacent spots (the open field and the soil of the forest) heat periodically variable, but with amplitude less in the second than in the first, while the phases and periods are substantially alike. The problem then consists in finding the distribution of temperatures in the soil at any selected time; or, in this case, it is the finding of the difference of temperature under the two spots at any depth and any time.

The forest acts on the soil chiefly by serving as a screen. Free insolation and free radiation to the sky are prevented by the leaves, trunks, branches, and the forest-litter. Thus the heat which reaches the forest soil is lessened, and the amplitudes of its annual or daily change are decreased; hence, the

mean effect of the forest will be a cooling one, and as both the maxima and minima of temperatures are cut down, the general result will be a moderating one. The quantity of these effects is modified by the relations of the forest to precipitation, by differences in soil, by the amount of cloudiness, by the character of the trees, by altitude above sea-level, by the exposure of the surface (its aspect), and by latitude. The character of the soil and the distribution of water in the soil are especially effective in modifying the influence of forests on soil temperature. The color of the soil, its texture, its capacity for the conduction of heat, would modify the relative temperature of forest soil were the soil alike in and out of the forest. But, as a matter of fact, the forest adds some peculiar materials to its soil, and modifies the water-contents so that the soil in the forest can never be exactly like that outside. It is probably to these variable effects that are chiefly due the irregularities in the figures to be given.

2. *The Observations Used.*—The set of forest observations of which I have made the most use are those of the German stations, the publication of which is edited by Dr. Müttrich.* These observations began in 1875 and still continue. They are taken at numerous stations scattered over the German empire, and are conducted on a uniform and well-arranged system. The geographical positions and brief descriptions of these stations are given in Table I.

Distances and elevations are given in feet. When the series of observations is longer than ten years, only the last ten are used because the earlier two or three years of observation show evidence of lack of uniformity and do not seem so strictly comparable as the later. The station at Carlsberg was changed in February, 1886, but as the two stations were alike in kind (at high elevation and with evergreen trees) I have used them together. The woods at Lintzel station are so young that treetop observations were not attempted.

In addition to these observations I have used those of Dr. Ebermayer,† who was a pioneer in this method of studying the

---

* Jahresberichte über die Beobachtungs-Ergebnisse der von den forstlichen Versuchsanstatten des Königreichs Preussen, des Königreichs Würtemberg, des Herzogthums Braunschweig, der Thüringischen Staaten, der Reichslande und dem Landesdirectorium der Provinz Hannover eingerichteten forst-meteorologischen Stationen. Herausgegeben von Dr. A. Müttrich, Professor an der Kgl. Forst Akademie zu Eberswalde und Dirigent der met. Abtheilung des forstlichen Versuchswesens in Preussen, Berlin. Annual.

† Die physikalischen Einwirkungen des Waldes auf Luft und Boden, etc., begründet durch die Beobachtungen der forst.—met. Stationen im Konigreich Bayern, von Dr. Ernest Ebermayer, Professor etc., Aschaffenburg, 1873.

forest meteorological problem. He used the observations from six field and forest stations in Bavaria and one in Bohemia, but the only published series of his, known to me, is that of the preceding reference and is only one year long. His results labor under the disadvantage of being drawn from too short a series of observations, but they are reliable as to the kind of effect produced by woods in the soil. His deductions as to the quality of these effects could, naturally, not be expected to be so exact as those afforded by a longer series of observations.

I have also made much use of the various papers published by Dr. Wollny of Munich. They have been generally published in his serial *Forschungen auf dem Gebiete der Agrikulturphysik.* The observations are usually in brief series, made to study individual aspects of the problem.

TABLE I.—GERMAN METEOROLOGICAL STATIONS.

Name.	Geog. Position.			Field Station.		Forest Station.		Years of Obs. used.
	Lat.	E. Long.	Alt.	Description.	Dist. from Forest.	Description.	Dist. from margin.	
Fritzen	54°50′	38°13′	98	Cultivated fields	262	Spruces, Birches, etc.	459	10
Kurwein	53 34	39 9	407	Cult.; swampy meadow near	679	80-140 yr. Pines	433	10
Carlsberg I	50 28	34 2	2352	Wet meadow	591	45 yr. Spruces	591	7
Carlsberg II	50 28	34 0	2489	......	591	80-100 yr. Spruces	623	3
Eberswalde	52 50	31 29	77	Cultivated fields	410	45 yr. Pines	869	10
Schmiedefeld	50 36	28 28	2231	Stony, aspect E.	984	60-70 yr. Spruces	492	7
Friederichsrode	51 22	28 14	1158	Between street and cult. land	367	65-85 yr. Beeches	1138	10
Sonnenberg	51 45	28 10	2549	Meadow in moor	328	45-50 yr. Spruces	650	10
Marienthal	52 16	28 38	469	Cultivated	984	60 yr. Beeches	656	10
Lintzel	52 59	27 55	312	Lüneberg Heath	......	Young	......	7
Hadersleben	55 16	27 9	112	Cultivated	410	70-80 yr. Beeches	394	10
Schoo	53 36	25 14	10	Swampy	656	20 yr. Pines	1640	10
Lahnhof	50 53	25 54	1975	Cultivated	2461	70 yr. Beeches	640	10
Hollerath	50 27	24 3	2005	Cult. and meadow.	361	45 yr. Spruces	328	10
St. Johann	48 29	26 59	2493	Stony field	1640	100 yr. Beeches	656	5
Hagenau	48 50	25 28	500	Betw. wet meadow and cult. land	4167	55-65 yr. Pines	2192	10
Neumath	48 59	24 57	1159	Meadow, NW slope of Vosges Mts.	820	45 yr. Beeches	820	10
Melkerei	48 25	24 57	3071	Forest meadow	3937	60-80 yr. Beeches	5249	10

3. *The Method* employed is the treatment of the periodic curves by harmonic analysis. The series for the temperature in forest soil has the same period and phase as that for the soil under open fields. They differ only in amplitudes; their difference will therefore be another harmonic series which will express the changes of temperature in forest soil as compared with the soil of open fields. Its amplitudes will be the ampli-

tudes of these changes and its epochs the corresponding times. The observations seemed to me to have been continued long enough to give results by this analysis which would be correct in kind and at least suggestive of the quantitative differences in temperature.

The use of harmonic analysis, especially in such a case as this where the inexactness of the observations, the numerous sources of disturbance, and the surplus of equations over the number of unknowns required, render necessary the employment of the method of least squares, is very laborious, but the labor can be very much lessened by judicious arrangement of the work,* and especially by selecting for normal places such as give equal parts of the circle. I corrected by interpolation the monthly values to reduce them to equal twelfths of the year. I treated all monthly means for ten years as of equal weight; for between seven and ten, they were weighted for the number of years; for less than seven they were rejected.

The computation was carried out to terms of 4θ, principally as a check and to get an idea of how completely the four periods represented the series of means. When all four periods were used the means were usually represented to a probable error of $\pm 0.03°$F, and the amplitude of the 3θ period was usually not more than 0.2° F., that of 4θ about 0.1 F.

4. *The Mean Annual Difference.*—By combining all the stations for the period of ten years (1879–1888), and thus getting nearly 150 years of observation in all, the harmonic solution gave the value in Table II in which the 3θ and 4θ periods are omitted. The degrees are Fahrenheit's.

TABLE II.

Depth.	Average.	Annual Period.		Semi-Annual.	
		Range.	Date of Change.	Range.	Date of Change.
Surface	−2.60°	7.82°	March 31.	1.32°	May 7.
5.9 inches	−1.89	6.44	April 4.	1.30	May 11.
11.8 inches	−1.68	5.88	April 5.	0.98	May 14.
3.94 feet	−2.03	5.66	April 26.	0.62	May 30.

* Suggestions regarding this may be found in Thomson and Tait's *Natural Philosophy*, Vol. I, Part 1, p. 455. In the *Phil. Magazine* (4th Ser. Vol. XXII, 1861, 23–34, 121–135), Sir William Thomson demonstrates the series and gives its application to a case of underground temperatures.

The second column gives the mean annual difference between soil temperature, in the woods and out, in the seventeen German stations described. If we represent by *W* the mean temperature under woods, and by *O* that under open fields, we find that *W—O* is negative at the surface and all the way down to four feet in depth. Ebermayer in a year's observations reached a result of the same kind. In German feet and degrees Fahrenheit, his results were: At surface, —3.59°; at six inches, —3.14°; at one foot, —3.29°; at two feet, —3.53°; at three feet, —3.43°; at four feet, —3.42°. *

Similar results were found at the Swiss stations, Interlacken, Bern and Pruntrut, in the twelve years from 1869 to 1880† where the means are: At surface, —4.13°; at 11.8 inches, —3.26°; at 1.97 feet, —2.96°; at 2.95 feet, —3.14°; at 3.94 feet, —3.19°.

The rule therefore, that *W—O* is on the average negative in that part of the world, and probably elsewhere, is unmistakable. The forest makes its soil cooler than it otherwise would be. This is to be expected because the forest cuts off a part of the sun's heat from the soil and the soil would consequently have a lower temperature if it had the reradiating opportunity that the soil has in open fields. As a matter of fact its opportunity for reradiation is less because of the screen of living foliage and trunks and branches, and also because of the protecting power of the forest litter.

The greatest difference between the forest soil and that of open fields is at the surface. The German observations give a mean difference of 2.60° (ranging from 0.84° for Hadersleben to 3.95° for Melkerei). In Bavaria it was larger, (3.59°) and in Switzerland still larger, being on the average 4.13°. (Interlachen, —4.21°; Bern, —3.87°; Pruntrut, —4.32°). This is a fair measure of the average effect of the forest on the air-temperature. In the mean it tends to cool the latter by 3° or so.

But as soon as we pass below the surface we find that the differences do not progress uniformly. The temperature of the soil usually increases slowly and on a simple law as we descend to lower depths. Thus from the observations about Edinburgh it was found‡ that at the various depths mentioned the mean temperatures, for five years, were:

---

* Reduced from results *l. c.* p. 37

† Lorey, *Handbuch der Forstwissenschaft*, I, 36.

‡ Sir W. Thompson, *l. c.* 31.

	At 3 ft.	At 6 ft.	At 12 ft.	At 24 ft.
For Observatory....................	45.49°	45.86	46.36	46.87
For Experimental Gardens..........	46.13	46.42	46.76	47.09
For Craigleith......................	45.88	45.92	45.92	46.07

The materials of the soil were different (trap-rock, sand and sandstone respectively) so that the mean temperatures were not the same, but a simple inspection shows the gradual (and gradually lessening) increase in temperature. The MM. Becquerel have found a similar increase * down to a depth of 36 metres (118 feet). From a mean of fourteen years of observation at Paris, they found the mean at one metre depth to be 52.07° F., and at 36 metres, 54.39°, and at intervening depths the rate of increase was fairly uniform.

If there were nothing peculiar in the distribution of heat under a forest, the difference of temperature at different depths would be fairly constant or would change slowly and nearly uniformly. Observation shows however that this difference is least immediately below the surface and increases both upwards and downwards. That this is no result of accidental variations is shown by the fact that it is seen in a series of observations, twice daily for 150 years (over 100,000 comparisons) and also by the fact that it is about as visible in the thirty-six year Swiss series. Attention has apparently not been called to this before. It must be due either to a gain of heat in the upper soil for the woods which the open fields do not have, or in a relative economy of heat on the part of the forest, and this gain or economy must be most efficient in the upper part of the soil. A gain of heat may be found in the decomposition of the organic matter which is more abundant in the upper part of the forest soil, but this is small in quantity and the decay is so slow that its effects are probably not appreciable in the temperature. There are economies of the heat in forest soil over that in open fields in the relatively small evaporation in the former, in the protection against celestial radiation afforded by the forest-litter, and in the relatively bad conductivity of the richer forest soil. As the moist soil becomes warmed with greater difficulty than the dry, and the soil below the forest-litter with greater difficulty than that without it, the economy of the heat due to the three above causes must be great. Probably the most effective is that which depends on evaporation.

5. *The Yearly Periodic Change.*—The range in the yearly

Comptes rendus, C. 1426.

periodic difference, from the greatest cooling to the greatest warming effect, is twice the amplitude given in column three of Table II. It answers the question: What is the total range of the temperature of forest soil relative to the same depth in open fields? Its greatest value is at the surface and it decreases as we descend. On account of the protection referred to in the preceding paragraph the decrease of the range is rapid in passing from the surface to six inches below. From there the range decreases but slowly.

The range at the surface is 7.82°,—a large number when one considers that it is the result of the mean from very many observations. The absolute range would be much greater. The mean minimum,—or the average coolest temperature of the soil of the woods as compared with open fields, obtained by adding the general mean (—2.60°) to the half of the range (—3.91°), is —6.51° F. In midsummer this is the amount by which the surface temperature is cooler in woods than in the open. The amount by which the woods are warmer in midwinter is —2.60° + 3.91° or + 1.31°. Taking the different levels in succession, we have,

	Maximum in Summer.	Minimum in winter.
At surface	—6.51°	+ 1.31°
At 6 inches	—5.11	+ 1 33
At 12 inches	—4.62	+ 1.26
At 4 feet	—4.86	+ 0.80

From this it is evident that the forest tends to cut off the extremes. It is cooler in the forest in summer and warmer in winter, and the effect of the forest in reducing the heat is from four to six times that in tempering the winter's cold. The forest is not only a cooling, but it is also, and to a greater degree, a tempering agency, and its maximum tempering effect is found at the surface.

The dates in column four of the table are those at which the analysis shows that the annual periodic change passes from the warmer half to the cooler half. So far as the annual period is concerned, the maximum cooling effect occurs three months later and the warming one three months earlier. For the surface the maximum cooling falls on June 31, the maximum warming on December 31. As is the case with earth temperatures generally, the phase is retarded as we descend into the soil. At four feet it is twenty-six days later than at the surface.

The period during which the soil of the woods is warmer is briefer than the cool period, because the cooling effect is greater than the warming one. The date of change is about a month earlier in the spring and a month later in the autumn, making four months the duration of the season during which the actual temperatures of the surface of the woods averages warmer than that of open fields. These dates are retarded and the season restricted, slightly, as we descend in the soil.

6. *The Semi-Annual Period.*—It is to be always expected, in the use of harmonic analysis, if the data are not exact, that fictitious periods will appear, but these can usually be recognized by the smallness of the amplitudes and, still better, when there is a series of progressive values, by the irregularity in the progress of the amplitudes and epochs. Judged by these tests, the semi-annual period seems to be real,—not fictitious. The amplitudes are relatively large, they change quite regularly, and the retardation of the phase is even more regular than for the annual period.

It is not easy to resist the conviction that the semi-annual period is significant, but it is hard to see to what it can be due. It must be due to some cause or set of causes which recur semi-annually. Referring to the table, these causes must have a maximum cooling action at one-quarter period after May 7 and November 7, or at June 18 to 20 and at December 18 to 20; or they must have a maximum warming action six weeks before these first dates. A cooling action is much more probable than a warming one. An alternative is that it is something that occurs at one of those dates only and that its appearance at the other is fictitious,—due only to the analysis. The dates for maximum cooling are about the summer and winter solstices. For the summer solstice there are two suggestive facts; it is the time of the maximum altitude of the meridian sun, and it is about the time of the greatest leafiness of the trees, especially those with deciduous leaves. At the winter solstice we have the lowest meridian altitudes of the sun, and the deciduous trees are leafless, but they had been in this condition for a month before and will be so for two months more. On examining these two possible causes, it appears that the explanation may be of the following character: At the summer solstice the leafiness is greatest and the vigorous young leaves may be most spread out to catch the sun's rays. At the same time evaporation is most active because there is more water in the soil and because

the sun is longest above the horizon. From this may result a secondary maximum of cooling. At the winter solstice the sun is at his lowest, so low that at noon he is for some of the stations less than 12° high and for none is he 19° high. At this low altitude of the sun the shadows are much increased and even the bare trunks and branches become partial screens for the sun's rays, while the evergreens become very effective screens. This effect would be less before this time and less after, reaching its maximum at exactly the winter solstice.

If the above is the true explanation, then the deciduous trees would be most affected at the summer solstice, and the evergreens at the winter one. The amplitude of the deciduous trees for summer should be decidedly larger than for winter, and the summer amplitude for evergreens should be smaller than for deciduous trees while the winter one should be larger. To test this I have solved for each sort of forest, for each half of the year independently, and find for the surface: Amplitudes for deciduous trees, summer 2.73°, winter 0.98°; amplitudes for evergreen trees, summer 1.50°, winter 1.42°. This shows a very fair accord with the explanation I have given. It must be remembered that a solution made in this way does not give values which can be trusted except for comparison with each other.

The range of the semi-annual period at the surface is 1.32°; it tends to bring forward the maximum cooling effect of the woods to a slightly earlier date than that given by the annual period, and to increase the amount; on the other hand it tends to decrease and retard the warming winter effect. The range decreases as we descend, at first slowly, then rapidly, and the phase is retarded with some regularity.

7. *The Periods of Briefer Duration.*—The period with a duration of four months and that with a duration of three months were solved, chiefly to serve as a check on the computation. The amplitudes for the four depths in order were:

Period of four months (3θ)....................	0.16°	0.18°	0.17°	0.17°
Period of three months (4θ)....................	0.01	0.05	0.12	0.01

The range would be twice these figures. It is, it seems, never so great as 0.4°. It is of little meteorological importance, and the phases are irregular. I doubt if these periods are of physical significance. Such periods appear in the harmonic analysis of the earth temperatures analyzed by Sir William Thomson, but he does not attempt to explain them. Physical significance

is still less possible in this case where the data studied are the differences between temperatures of strata at the same depth.

8. *Comparison of Deciduous and Evergreen Trees.*—The forests selected for observation by the German service are about equally divided between deciduous and evergreen trees. Omitting Lintzel because the trees are young, Fritzen because the forest is mixed, and Eberswalde, in order to distribute the altitudes uniformly in each, we have among the rest seven stations in deciduous forests and seven among evergreens. Solving each set separately, we get

TABLE III.

Depths.	Deciduous.					Evergreen.				
	Average.	Annual.		Semi-Annual.		Average.	Annual.		Semi-Annual.	
		Range.	Date of Change	Range.	Date of Change		Range.	Date of Change	Range.	Date of Change
Surface.	−2.58°	8.42°	Apr. 2	1.74°	May 17	−2.62°	7.50°	Mch. 30	1.24°	Apr. 24
5.9 in...	−1.90	6.14	Apr. 9	1.46	May 19	−1.83	6.44	Apr. 30	1.24	May 2
11.8 in..	−1.70	6.46	Apr. 10	1.42	May 22	−1.71	4.94	Apr. 2	0.74	Apr. 27
3.94 ft...	−2.07	5.30	May 4	0.80	May 22	−2.20	4.76	Apr. 11	0.42	May 31

The most noteworthy conclusion from this table is, that there is not much difference in the action of the two kinds of trees. The average effects are very similar; at only one depth is the difference above 0.1°. The annual ranges are rather more diverse; that for deciduous trees is about one degree more than that for evergreens. The explanation of this is simple, and the only thing remarkable about it is, that the difference is not greater. When we compare summer and winter effects, we find both are in favor, generally, of deciduous trees.

	Summer		Winter.	
	D.	E.	D.	E.
At Surface	−6.79°	−6.37°	+1.63°	+1.13°
At six inches	−4.97	−5.05	+1.17	+1.39
At one foot	−4.93	−4.18	+1.53	+0.76
At four feet	−4.72	−4.58	+0.58	+0.18

The dates for the deciduous trees are somewhat retarded. The differences in the semi-annual period are relatively greater. The range for deciduous trees is about a half larger and the phases are more consistent.

In general, the difference between the two sorts of forests is

unexpectedly small. Their difference in foliage and the difference in the conductivities of their favorite soils would lead one to expect greater differences in their effects on ground-temperatures.

9. *Effects of Elevation Above Sea Level.*—To show this I selected seven stations of an elevation of 1975 feet and above, and seven of an elevation of 500 feet and below. The mean elevation of the first set was about 2400 feet; of the second about 240 feet. Lintzel was omitted, and evergreen and deciduous forests were about evenly distributed in each set. The solution gave the results of

TABLE IV.

Depths.	2,400 feet above sea-level.					240 feet above sea-level.				
	Average.	Annual.		Semi-Annual.		Average.	Annual.		Semi-Annual.	
		Range.	Change	Range.	Change.		Range.	Change.	Range.	Change.
Surface	—2.76°	6.96°	April 3	1.24°	April 28	—2.31°	8.48°	March 30	1.42°	May 13
5.9 in...	—2.11	5.72	April 23	1.18	May 3	—1.53	6.88	April 30	1.36	May 16
11.8 in.	—2.08	5.18	April 10	0.80	May 1	—1.16	6.24	April 3	1.30	May 19
3.94 ft...	—2.45	4.88	May 3	0.38	May 31	—1.60	5.88	April 24	0.82	June 1

It appears at once that there is an appreciable difference in average effect; the trees at low levels have an average surface effect of —2.31°, those at high levels of —2.76°, or twenty per cent. greater. The difference is even greater at some distance below the soil, due probably to the more stony character and better conductivity of the elevated soils.

On the other hand, the annual and semi-annual ranges are greater, by about the same percentage, on the lower levels. This is probably due to the greater exposure, the more complete air-drainage, and the less luxuriance of the trees at higher levels.

The dates of the annual period are somewhat retarded above, as might be expected. It is not so easy to explain the acceleration of the semi-annual dates.

10. *Effect of a Young Forest.*—Lintzel is a station in a forest so young that no trees could be found sufficiently large for a tree-top station. It would be interesting to see if its temperatures are only intermediate between those of woods and open fields, or if they show any difference of kind on the part of a

low and young wood. There were only seven years of observations available, and yet the results are fairly consistent with a probable error for a computed monthly value of ±0.3°. The results are given in

TABLE V.

Depths.	Average.	Annual Period.		Semi-Annual.		Ranges.	
		Range.	Change to cool	Range.	Change to cool	$_3\theta$	$_4\theta$
Surface.............	−1.25°	4.88°	April 7	2.68°	May 16	1.60°	0.80°
At 5.9 inches....	−0.94	3.24	April 7	1.98	May 18	1.40	0.40
At 11.8 inches....	−0.42	1.64	April 25	1.14	May 26	0.80	0.24
At 3.94 feet......	−0.58	2.78	April 20	1.40	June 18	0.28	0.30

The average effect and annual period are evidently only intermediate between a full grown forest and no forest. The semi-annual ranges seem remarkably large, but it is probably not significant as the ranges for the four-month and the three-month periods are also large. A seven years series of observations is, apparently, not long enough to give a good determination for the semi-annual range.

11. *Other Modifying Causes.* — The data available are not sufficient to make a general solution of the effects of other modifiers of the action of the forest. The mean cloudiness undoubtedly modifies it, for the action of a forest in cutting off insolation and celestial radiation is of the same kind as that of clouds. Clouds should tend to cut down the differences between soil-temperatures in woods and out. I found that by combining all observations in years and comparing them with the cloudiness, the average results were as follows:

Six years..................................Cloudiness 0.68 W—O = −1.46
Four years..................................Cloudiness 0.72 W—O = −1.33

It seems that for an increase of four per cent. of cloudiness there was a decrease of 0.13° in the mean difference between the temperature of the surface of woods and open fields. This result is of the kind to be expected, but appears suspiciously large in quantity, for it would make 82 per cent. of clouds eliminate entirely the average effect of the forest. On trying to make a general solution, however, I found that the average cloudiness did not vary enough to give me well conditioned equations.

The wetness and dryness of the soil must have a decided influence on the difference of the soil temperatures. The change in the thermal capacity and thermal conductivity of the soil which is caused by water, the heat taken up in evaporation, and the relative movements of air and water through the soil must have an appreciable effect on the temperatures of the soil. Elaborate studies have been made on the relations of the ground water to the soil, but they have not been made, so far as I know, in connection with forests. To show what is the nature of the effects to be expected, I will refer to Dr. Wollny's painstaking and elaborate studies.* He found that, for all the kinds of soil tried, moist earth averaged cooler than dry, and wet earth cooler than moist. Both minima and maxima of temperature are cut off in moist or wet earth as compared with dry, but in the wet more than in the moist, and the maxima more than the minima. Winter temperatures of moist earth are usually higher than those of dry.

An instructive series of observations were also made under circumstances which permitted—the control of the moisture in the soil. Two sets of bi-hourly observations were taken † at a depth of 4.9 inches in white quartz sand. One set continued from July 29 to August 3, the other was made on September 12, 13, 18, and 19. The results were as follows. The percentages are those of water in the soil, 100 being all the water the soil will contain without dripping.

Moisture.	Wet Soil. 1st Set.	Dry Soil. 2d Set.
20 per cent	—0.18°	—0.27°
40 per cent	—0.32	—1.03
60 per cent	—0.72	—1.10
80 per cent	—1.49	—0.88
100 per cent	—3.20	—0.83

From this it appears that, in general, the wetter the soil is, the cooler it is.

The composition and physical properties of the soil are undoubtedly modifiers of the action of the forest. The relation of these features to the temperature of the soil has received much attention, but the application of the results to the problem in hand presents many difficulties, because the very existence of a natural forest is generally an indication of a differ-

* *Untersuchungen uber den Einfluss des Wassers auf die Bodentemperatur.* In the Forschungen auf dem Gebiet der Agrik.—Physik, Vol. IV, Parts 3 and 4.

† *L. c.*, pages 27-29.

ence in the soil covered by it, and its continuation necessarily causes changes which make the soil of woods still more different from that of open fields.

The slope and aspect of the surface must also modify the action of the forest on the soil temperatures. Dr. Wollny has shown * that, on an experimental scale and with naked earth, the temperatures of the soil increase in range with a southern exposure, and with an increase of the angle with the horizon, while the range is less with a northern exposure and is intermediate with an eastern or western one, the former resembling the southern, the latter the northern. The forest influence on a slope would also be decreased by the less perfect screen of leaves as well as by the more perfect air drainage.

RAINFALL IN MICHIGAN—SEPTEMBER.

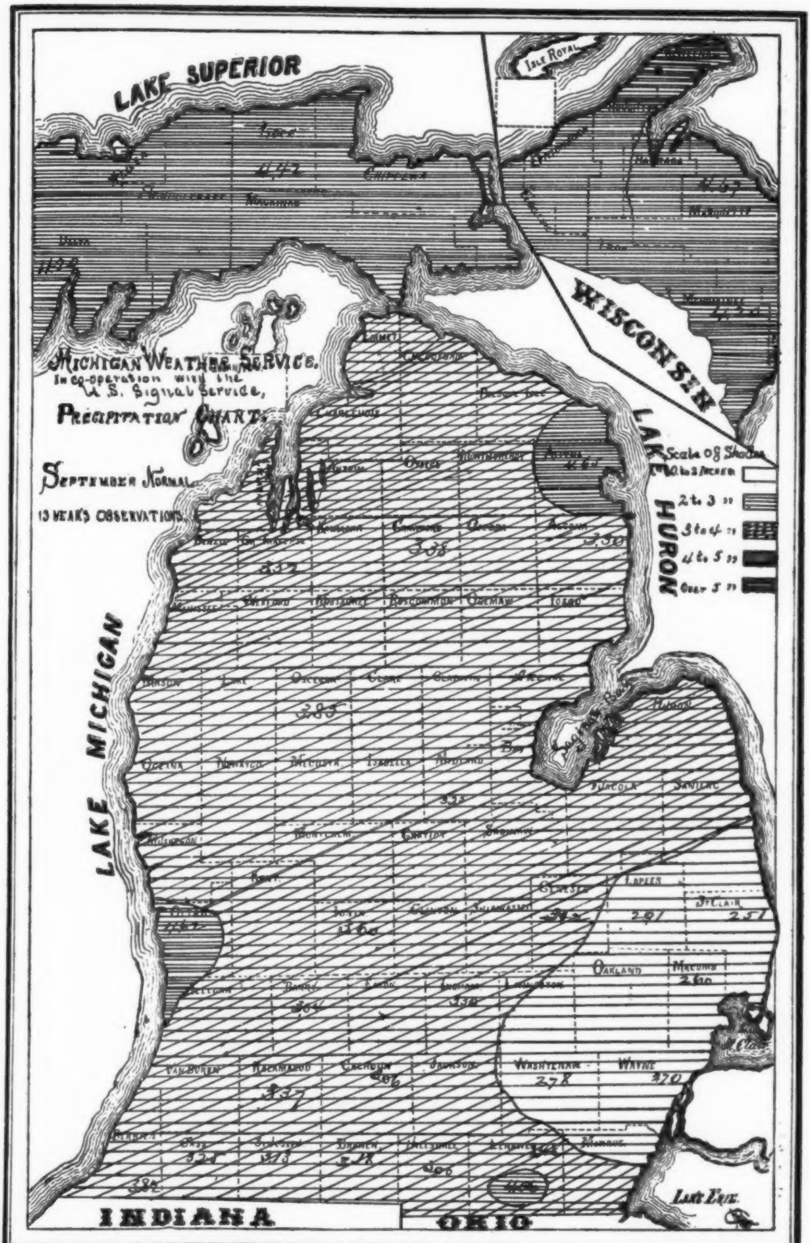
By N. B. Conger,
Director State Weather Service.

The average rainfall for the State for the month of September is 3.22 inches, which is distributed as follows: For the upper peninsula the average is above four inches, and for the lower peninsula the average is from two and one-half to four and three-quarters inches. An average rainfall of over four inches is found only in three localities in the lower peninsula, viz.: Alpena county, Ottawa, and a small portion of central Lenawee county. In the extreme eastern counties along the southeast borders the rainfall will average about 2.75 inches, as will be noticed by reference to the accompanying chart.

The rainfall for this month is subject to considerable extremes, from a maximum of 12.71 inches at Marquette in 1885 to 0.28 inches at Port Huron in 1877. Large rainfalls have been reported in every section of the State during the past fifteen years, but the records would not indicate that they occur frequently or follow in successive years.

It will be noticed that the heavy rainfall has increased its area in the upper peninsula, over that occupied during August, and also the same effect will be noted in the lower peninsula—that the average amount of rainfall has increased somewhat during this month. This, of course, is but natural, as the low areas or storms are more frequent during September than during the

* *Forsch. Agrik.-Physik.*, X. Heft 1.


LAKE SUPERIOR
ISLE ROYAL
WISCONSIN
MICHIGAN WEATHER SERVICE.
In co-operation with the U.S. Signal Service,
PRECIPITATION CHART.
SEPTEMBER NORMAL.
13 YEAR'S OBSERVATIONS.
LAKE HURON
Scale of Shading
2 to 3 "
3 to 4 "
4 to 5 "
Over 5 "
LAKE MICHIGAN
Saginaw Bay
Oakland
Washtenaw
Wayne
Lake Erie
INDIANA
OHIO

month of August, and the general trend of the storms are more over the upper peninsula; the lower peninsular is generally on the south half of the storms, and the rainfall decreases towards the southeast.

The prevailing winds of this month are southwest and the same causes that operated on the rainfall during August will prevail now, but as the storms are more general and the rainfall more frequent, the amount distributed over the state is more even than in the preceding month.

Light rainfalls are more liable to occur in the southern tier of counties, and in the extreme southeast counties, than in other portions of the State, with the exception of the counties of Berrien, Cass and Van Buren, where the natural conditions of the air currents bring it moisture-ladened over this portion and deposit it in sufficient amounts so that these counties seldom suffer from the lack of rainfall during this month.

The average rainfall for September is sufficient to make it one of the rainy months of the year, and the rainfall generally occurs in storms which distributes the fall over the entire State and not in local showers, as happens during the summer months.

CURRENT NOTES.

The Formation of a Tornado.—We owe to Professor L. Estes, of Grand Forks, N. D., the following clipping from the Minneapolis *Journal* for July 14, 1890. It relates to the severe tornado near Minneapolis just before this date.

At the New Brighton and the Twin City stock yards the tornado cloud was plainly seen while in process of formation. It was to the northward, and was finally seen to move off toward Gervais with great speed. In Minneapolis there were many interested watchers of the heavens. The panorama of clouds with their irregular shapes and changeful, ominous tints was a majestic and terrible one. J. F. Hogle made an attempt to photograph the tornado cloud formation which was seen to the north, but it was so far away that he was not able to get a good negative. Its funnel shape could be distinctly seen.

The formation of the tornado is thus described: First, there was a concentration of clouds at a certain point from all directions—all rushing together with great velocity. As detached clouds came in contact with the concentrated masses, they would be seized upon by an invisible power and hurled downward with terrific force, but all the time the central cloud grew more and more dense until it became a black and impenetrable mass.

While this formation was in progress, and the mass of clouds was seething and boiling, there was no perceptible movement forward. At last, however, a slim, snake-like formation shot out from the bottom of the mass. As the stem or offshoot shot downward, it began to revolve, slowly at first, but increasing in velocity as it neared the earth. As it traveled earthward it constantly drew to it from the mass from which it sprung, until it had the appearance of an elongated cone with the small point downward. Finally the small point seemed to come in contact with the earth and then the whole mass, as if under the control of one master power, commenced to move rapidly eastward, and so continued until it struck the heavy rain storm coming up from the east, by which it was broken up and dissolved.

THE KANSAS HOT WINDS.—Sergeant Jennings of the Kansas Weather Service, and Professor Curtis, of the U. S. Geological Survey, have combined forces in the study of these winds and a preliminary report on them appears from Sergeant Jennings in the *Trans. Kansas Academy of Science,* XII, Part I. Something of the methods and results is indicated in the following extract from this paper:

In answer to a circular a number of "hot winds" have been reported. During July these occurred on the 5th, 6th and 7th, 15th, 16th and 17th, and 26th and 27th, that of the 15th, 16th and 17th, being the most extensive and disastrous.

A resumé will be interesting. On the morning of the 5th there is an area of diminished pressure central near the Black Hills, in Dakota. Its indraught extends to the lake region on the east and to Texas on the south. At Bismarck the wind is northeast and the barometer 29.56; at Rapid City the wind is west and barometer 29.52; while over the Lake Erie the barometer is 30.20, and in Texas 30.06. By the time of the evening observation, 7 P. M. central time, a change has appeared on the Government maps. A *hot wave* (remember the time of day—7 P. M., that is after 6 P. M., actual time) extends from North Platte, Neb., to Fort Custer, Mon., covering the southwest half of Dakota, with temperatures as follows, viz.: North Platte 94°, Valentine 96°, Huron, Dak., 94°. Bismarck 90°, Fort Sully 98°, Rapid City 92°, and Fort Custer 90°. An area of lower barometer has developed in the mountain regions of Idaho, Montana, and Wyoming, or has advanced from the west and is now central in that region, drawing the wind from the south across Kansas and Nebraska at from 16 to 24 miles per hour. During this afternoon occurred some *hot winds* in the western counties of our State. In Morton, Stevens, Grant and Stanton the temperature reached 99°, in Trego and Grove 100°, and in Thomas 102°. At North Platte, Neb., it reached 102°, and at Valentine 106°.

On the morning of July 6th this area of low pressure has moved southeastward, and is now central in the northwestern part of Nebraska and southwestern part of Dakota. This being Saturday, no afternoon map was issued. The 7th being Sunday, no morning map was issued, but the afternoon map shows the low pressure divided, a part being cen-

tral in northwestern Iowa, and the other over the Panhandle of Texas, while the general current of the wind over Kansas is from the southeast. The maximum temperatures of this day were lower in Nebraska than in Kansas. At Dodge City it was 94°, at Gibson 105°, at Lisbon (Gove county) 100°, at Offerle (Edwards county) 98°, at Englewood 97°, at Hugoton 87°, and at Colby 98°. The general current of the wind over Kansas was changed to east and northeast, responding to an area of low pressure over the Panhandle and New Mexico.

The rain of the 8th, and the high pressure following, materially lowered the temperature for the next few days.

An extensive area of low pressure in the mountain regions on and after the morning of the 12th, kept our winds southerly until the night of the 17th-18th, the maximum temperatures of the 17th, being the maximum for this hot wave, were as follows: North Platte 100°, Colby, Kansas, 103°, Libson 108°, Gibson 114°, Dodge City 100°, Offerle 103°, Hugoton 100°, Englewood 101.5°, Fort Elliott, in the Panhandle, 102°, Fort Sill, Indian Territory 96°, and El Paso, Texas, 100°.

But as this paper is only preliminary to a fuller discussion of this subject at our next annual meeting, its object at this time being to show the line and method of research, its purpose is deemed fulfilled.

ERRATA.—In the June JOURNAL, in M. Léon Teisserenc de Bort's article on the laws of "Distribution of Cloudiness over the Surface of the Globe," Figure 3, (p. 58) representing the hemisphere of Europe, Asia and Africa in July, should be reversed, so that what is now the south pole becomes the north pole and *vice versa.*

In the report of Mr. Tripp's paper at the Royal Meteorological Society, (p. 144, July number), it is stated that "The English records began in 1726." Mr. Symons tells us that this should have been the English *continuous* records. He says in a note to the editors: "The first complete year of which we have a record is 1677, twelve years before our French friends and their record, like ours, is broken. Our first record is from Townley, near Bromley, in Lancashire, and ran from 1677 to 1703, but hitherto I have not been able to find the values for 1687, 1688, 1694, 1695 or 1696."

BOOK NOTICES.

EXACT THERMOMETRY.*—The author of the book, the title of which is given below, while recognizing the high scientific value of gas thermometers, thinks that the mercurial thermometer,

* Traité Pratique de la Thermométrie de Précision, par Ch. Ed. Guillaume, Docteur ès Sciences, attaché au Bureau International des Poids et Mésures, Paris. Gauthier-Villars, 1889, Octavo, xv + 336 pages, 4 plates.

within the limits of temperature at which mercury remains liquid, is capable of giving entirely accurate measurements of temperature. Moreover, it is easy, contrary to the general opinion, to make a set of mercurial thermometers which will give identical results for temperature. These considerations, together with the fact that the convenience of the mercurial thermometer, determines its employment wherever it is capable of being used, and that the promising electrical methods are still in their infancy, lead the author to devote his book almost entirely to this form of instrument.

With the study of this instrument are given studies of several features which have a more general scientific interest. These are such as the permanent and temporary deformations and the superficial modifications of glass, and the numerical relations of dilatations of bodies with increase of temperature. Questions of pure theory have been omitted, as have also the classical apparatuses described in the treatises on physics, and there is nothing in the book which even suggests the periodic errors which Professors Rogers and Marvin, and Mr. Woodward have been discussing. Certain auxiliary apparatuses, which are not generally known, are described in great detail.

The fact that the author is connected with the International Committee of Weights and Measures is sufficient guarantee of the scientific character of this treatise.

STORM-TRACKS, FOGS, AND ICE OF THE NORTH ATLANTIC.*—The condensed information in Finley's Sailor's Hand-book will be of great value to the class to which it is addressed, but it will also be of value to meteorologists. It will be all the more useful to the latter, and carry more confidence with it, from the fact that the data on which the charts are made are given in tabular form. But the author does not forget the class to which he especially appeals, as is shown by the six or seven pages of simple, explanatory matter which precede the tables.

The twelve monthly charts of storm-tracks contain, each, all the paths of the storms charted for the month on the North Atlantic for eleven years, ending with 1884. The tracks are in red and the effect is pleasing. Many interesting conclusions can be drawn directly from these charts. For instance, the storm-

---

*Storm-Track, Fog, and Ice Charts of the North Atlantic Ocean and Hurricane Track Charts of the Gulf of Mexico, by Lieut. John P. Finley, Signal Corps, U. S. Army. Assistant to the Chief Signal Officer of the Army, Boston, Mass. The Standard Publishing Company, 1889. Large octavo, 30 pages text and 51 charts.

tracks show but a small tendency to change their latitude with the season on the North Atlantic. The shifting is so slight that it would puzzle one to tell whether it was northward or southward in summer. On the North American continent the northward shifting in summer is very marked. The number of storm-tracks crossing our coast between Florida and the Straits of Belle Isle is, to a very marked degree, greater than the number which reach the entire west coast of Europe—except possibly in August. For many months this is true when we count only the storm-tracks leaving the coast between New York and the Straits of Belle Isle. There is a remarkable freedom from Atlantic storms in central and southern France and in Spain, but there is a noteworthy complex of storm-tracks over Switzerland, northern Italy, and the gulf of Genoa in most months.

The hurricane track chart for the North Atlantic is made with 79 selected hurricanes dating from October, 1780, to November, 1888. In addition, a chronological list of the principal West Indian hurricanes is given. It begins with that of February 12, 1493, and numbers 494. The tendency of these storms to hug the coast appears plainly on the map. The tracks usually begin just to the eastward of the Windward islands, but one begins on the coast of Africa, east of Cape Verde islands, and another, beginning west of the Canaries, travels northeastward, and crossing Madeira, ends in Spain. The distribution of the tracks on this chart is doubtless much affected by the density of ocean commerce; if all parts of the North Atlantic were equally frequented, the distribution of hurricane tracks might be different.

The hurricane chart of the Gulf of Mexico is compiled from fifty-six storms, dating from June, 1831, to October, 1888. This chart includes the *vinesas* as Mr. Everett Hayden proposes to call them (see this JOURNAL Vol. V, p. 459). It is, so far as we recall, new, and it is certainly of very great interest, for these are the hurricanes that affect the weather of the inland United States. One of these hurricanes passed westwardly into Mexico, three northwestwardly into Texas, and three reached Illinois.

There are thirteen storm frequency charts, one for each month and one annual. They are compiled from the charted storms for seventeen years (1865, 1868, 1874 to 1888). Noteworthy is the relatively great frequency (20 to 30 per year) in the tongue-shaped area having its base from New Brunswick to New York and extending three-fourths of the way to Ireland. The tracks

of the incoming British steamers lie mostly within this and the outgoing ones to the south of it.

Space forbids a discussion of the fog and ice charts (each twelve in number) though they are novel and full of interest. Readers must go to them for further information, but we will not refrain from compiling from Lieut. Finley, a table of the average monthly frequency of storms and ice on the North Atlantic. The ice reports are of course incomplete and relate rather to the appearance of the ice in the usual tracks of vessels. From this point of view, we may consider the three last months of the year as free from ice.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average storm tracks for 11 yr's.	22.1	20.1	22.4	18.4	16.1	15.2	14.9	16.6	16.9	18.2	20.0	19.0	219.9
Total West Indian hurricanes..	4	6	12	6	6	11	49	99	96	79	18	8	394
Total hurricanes in Gulf........	2	3	0	0	1	4	4	12	12	15	3	0	56
Ice reports lat. 35° and north...	14	27	36	42	57	19	39	6	3	0	0	0	243

A Study of Weather Types.—M. G. Raymond of the French Meteorological Society has recently published a little book * which is a model of what should be done in this country. M. Teisserenc de Bort, in a conference at the Scientific Congress of Limoges, which forms the introduction to the volume, after dividing the meteorologists into two schools—the dynamic, which studies the barometric depressions and constructs charts of their trajectories, and the ancient school, which pursues the static method of grouping the phenomena with relation to divisions of time and space and taking monthly, seasonal or annual averages for geographic points—states that neither is the only good method and that both may be useful to establish equations of condition to eliminate certain unknown factors and to arrive at the truth. A method combining the two above mentioned for the benefit of weather forecasts is that developed by M. Teisserenc de Bort under the name of the great centers of action of the atmosphere, and based on the study of mean and daily synoptic charts, which show that there exist in the atmosphere a certain number of maximum and minimum pressures which control the surrounding atmospheric circulation and influence the weather of the countries which they cover.

* Les Grands Centres d'Action de l'Atmosphère. Leur Influence sur de Temps, d'après les recherches de M. Léon Teisserenc de Bort. Paris, Gauthier-Villars, 1890.

It is the influence of this distribution of pressures that M. Raymond analyzes. After considering the mean distribution of pressure over the globe, the author defines the principal centers of action of the atmosphere, as follows: The equatorial barometric minimum, the maxima in about latitude 35° on each side of the equator, the minima which are found in winter over the oceans and in summer over the continents. The exceptionally cold winter of 1879–80 in Europe and the influence of the great centers of action of the atmosphere in abnormal winters are considered and the situations which are favorable for the production of cold or mild winters are discussed. The distribution of pressure is then grouped in ten types according as the resulting weather is cold, cold and damp, warm, warm and rainy, dry, etc. The author concludes by insisting on the importance of a knowledge of the conditions preceding the movements of the great maximum and minimum pressures for long-range weather predictions; and he considers that for this purpose as much of the surface of the globe as is possible should be included. This study, he thinks, will be greatly aided by the daily telegrams from America which contain also data from recently arrived ships. The author, however, recognizes the fact that much investigation will be necessary to interpret them because the relations of the various positions of the centers of action are not yet completely determined, but he believes that in this way weather prediction will enter upon a new phase so as to extend several days in advance and, eventually, even so far as to announce the general character of the seasons.

M. Raymond in thus classifying weather types in France, and Dr. Van Bebber who has done the same in Germany, have commenced an investigation in Europe which should find a wide and practical field for continuance in the United States. A. L. R.

HARVARD COLLEGE OBSERVATORY METEOROLOGY.—The meteorological publications of Harvard observatory during 1889 are a most valuable addition to the American literature of this subject. They are as follows, (the volume numbers referring to the Annals of the observatory):

No. 1°. Vol. XIX, Part I. Meteorological observations made during the years 1840 to 1888 inclusive, at the Harvard College observatory, under the direction of William Cranch Bond, George Phillips Bond, Joseph Winlock, and Edward C. Pickering, successive directors of the observatory.

No. 2°. Vol. XX, Part I. Observations made at the Blue Hill meteorological observatory, in the year 1887, under the direction of A. Lawrence Rotch.

No. 3°. Vol. XX, Part II. Observations made at the Blue Hill meteorological observatory, in the year 1888, under the direction of A. Lawrence Rotch.

No. 4°. Vol. XXI, Part I. Observations of the New England Meteorological Society in the year 1888.

No. 5°. Vol. XXII. Meteorological observations made on the summit of Pike's Peak, Colorado, (Lat. 38° 50′ N., Long. 105° 2′ W., elevation 14,134 feet), from January 1874 to June 1888, (made under the direction of Generals Myer, Hazen and Greely, the successive chief signal officers, U. S. Army), pp. xiv + 475.

No. 1. This volume of 157 pages contains the results of the meteorological observations which have gone hand in hand with the astronomical work of the Harvard observatory during a period of nearly fifty years. At various times partial publications have been made of portions of this data, as for instance in the Mem. Amer. Acad. Arts and Sciences for 1846, American Almanac 1844–57, Patent Office Reports 1856–1859, and in some of the Signal Service publications. The present volume contains: Chapter I. A history and description of the series of observations, and the instruments by means of which they were made. Chapter II. Monthly and annual means, for the various hours of observation. These include barometer readings reduced to freezing point, thermometric means (various thermometers), dry bulb of the psychrometer, relative humidity, wind force (estimated on various scales), amount of clouds on scale of 0–10, monthly and annual barometric means, and monthly barometric maxima and minima, monthly and annual thermometric means, and monthly thermometric maxima and minima, monthly and annual temperatures computed from mean of maxima and minima, monthly averages and annual relative humidity, monthly averages and annual wind force, monthly and annual amounts of clouds and rainfall. The gaps in these tables are too numerous to mention. A very valuable list is given of auroras, and also of thunder and lightning; and some miscellaneous phenomena such as temperature of wells, river, rain and cellars; solar halos, parhelia and lunar halos; and scattered general remarks on weather, clouds, earthquakes and meteors.

No. 2 has been remarked on in this JOURNAL, Vol. VI, page 40.

No. 3 has also been mentioned, see Vol. VI, page 531.

No. 4. If this volume of 105 pages is the first of a series of annual volumes, its appearance is of unusual importance to meteorologists. Professor Pickering's co-operation with the meteorological observers of New England, just at the point where so much data is allowed to lie uncared for and unused cannot be too highly appreciated.

The first twenty pages is occupied by a meteorological summary for the year 1888. We learn that there were 172 stations; but, owing to the voluntary system and other causes, the average number reporting each month was only 143. The weather of each quarter of the year is remarked on: various data concerning the cyclonic areas are given for each month, and thunderstorms and heavy rainfalls are commented on. There are ten tables and twelve charts. Table I contains names and locations of stations with observers. Table II is the summary of observations for 1888; and these include for temperature, the mean daily range, highest, lowest, absolute range, and mean from the maximum and minimum, and tri-daily observations: also amount of precipitation and amount of unmelted snow, total number of days and average number per month. Table III, monthly mean pressures and relative humidity for twenty stations. Tables IV, V, maximum and minimum pressure for each month, and date. Table VI, VII, monthly temperature and precipitation normals and departures for selected stations. Table VIII, maximum wind velocity and total wind movement for each month for selected stations. Table IX, monthly summary of temperature and precipitation for each station. Table X, daily precipitation at certain stations.

No. 5. This is by far the most important of the publications mentioned here. The Chief Signal Officer has furnished the Pike's Peak observations from January, 1874, to June, 1888, and Professor Pickering has had them printed *in extenso.* Up to July, 1881, the observations were made tri-daily, and from then to October, 1886, five times a day, and from then on to the close, tri-daily. The observations include pressure, temperature (and maximum and minimum), relative humidity, wind velocity and direction, precipitation, weather, upper and lower clouds, giving kind, amount and direction. There are also given hourly observations of pressure and temperature at Colorado Springs and Pike's Peak for August and September, 1874. Hourly wind

movement for each hour (miles per hour) at Pike's Peak from January, 1874, to January, 1876. Mean hourly wind movement at Pike's Peak for each month from January, 1874, to June, 1888. The average pressures and temperatures observed at 5 A. M., 1 P. M. and 9 P. M., for each month from January, 1874, to June, 1888. Total precipitation for each month from January, 1874 to June, 1888. There are also given sixteen pages of extracts from the observers' journal, in which will be found much interesting matter concerning electrical storms. It has frequently been deplored that these valuable data, from the most elevated observatory in the world, have so long been withheld from meteorologists; and their use by skilled meteorological investigators will be frequent and will continue for a long time to come. The preparation of the data for publication was intrusted to Professor Hazen, whose well known enthusiasm for high level meteorology guarantees a careful supervision. We cannot close this notice without expressing the regret, shared by all students of Meteorology, that the opportunity for making hourly observations at Pike's Peak either by direct observation or self-registering instruments was not utilized. Had this been done the observations would have been many times as valuable as those actually made.

F. W.

PUBLICATIONS RECEIVED.

"Met. Ergebnisse der Fahrt des Ballons 'Herder' vom 23 Juni, 1888." By Dr. V. Kremser. Octavo, 22 pages. Reprint from the *Zeitschrift fur Luftshiffahrt*, 1890.

"Pilot Chart of the North Atlantic Ocean, for August, 1890." Published at the Hydrographic Office, U. S. N., Capt. H. F. Picking, hydrographer. In addition to the usual data it has an account of the great hurricane of August, 1887, with three maps, and a report of bottle-papers picked up.

"Monthly Review of the Iowa Weather and Crop Service, April and May, 1890." Gr. octavo, 44 pages. J. R. Sage, director; Geo. M. Chappel, M. D., Signal Service assistant; Central Station at Des Moines. It contains, besides the usual meteorological summaries, several articles on Iowa and its physical conditions. This is the initial number. Also No. 3, June, 1890,

24 pages, with several articles of general and meteorological interest.

"Ensayo de Meteorognosia de la Ciudad de Puebla." By Professor B. G. Gonzalez, Civil Engineer, Puebla, 1889. Octavo, 28 pages, with several tables. This is an attempt to make a long-range prediction (for a year) for Puebla on the strength of the record of observations already made.

"Report of the New York Meteorological Bureau, May, 1890." Quarto, ten pages, with a map of mean temperatures and one of precipitation. Professor E. A. Fuertes is director, E. T. Turner, C. E., consulting meteorologist, and I. G. Gardner, Signal Service assistant. The central office is at Cornell University, Ithaca.

"Observatorio Met. del Colegio del Estado de Peubla," Abstract for June, 1890. Don Miguel Bernal is president of the college and Don B. G. Gonzâlez is the director of the observatory. The position of the observatory is: latitude 18° 3′ N., long. 98° 12′ W., altitude 7118 feet. This is a double quarto sheet with the daily valuesof the usual meteorological elements.

"Doane College Meteorological Studies, No. I. Rainfall at Nebraska, 1849 to 1880." Compiled by Goodwin D. Swezey, Director of State Weather Service. Octavo, 15 pages. Professor Swezey's compilation is for sixty-six stations and includes about 375 years of observation; it gives the mean monthly and annual values, the dates and amounts of largest and smallest monthly fall the latitude, longitude and elevation of the station, and the name of observer.

"Monthly Weather Review for May, 1890." Prepared, under the direction of Gen. Greely, Chief Signal Officer, by Captain H. H. C. Dunwoody. It contains, besides the usual compilations of the service, the monthly temperatures (19 years), and precipitation (16 years), at Taunton, Mass., by A. F. Sprague; monthly temperatures at Santa Fé, N. M., (41 years, with some gaps); average hourly departure of the mean hourly pressure from the mean of the twenty-four hours at Washington, D. C.; precipitation at Fort Brady, Mich., (from 1836 with a large gap from 1856 to 1872), by the army surgeons; and precipitation at Miami, Mo., (43 years) by Judge Ferril.

C

THE
Spe
Stu

For

Wel
try,
den

Ser
tor

STANDARD THERMOMETER.

LEGIBLE.

5 inch Dial.

$2.50.

ACCURATE.

8 inch Dial.

$2.50.

(Metallic.)

Special Thermometers for Meteorologists with or without Telemeter attachments.

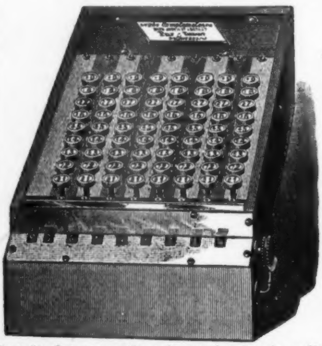
AGENTS:

THE FAIRBANKS SCALE HOUSES

In the principal cities of the United States.

COMPTOMETER

(TRADE MARK.)



All Arithmetical problems are solved rapidly and accurately by the Comptometer. It is operated by keys like the typewriter and gives entire relief from mental strain. It is the only machine on which addition can be performed faster than with the pencil, and is adapted to all commercial and scientific computations.

"We feel that we could not do without it, without causing us great inconvenience."—GEO. L. CHASE, President Hartford Fire Insurance Co.

"It not only does the calculations many times quicker, but it also saves time in not having to write down the numbers for calculation."—DR. DANIEL DRAPER, Ph. D., Director Meteorological Observatory, Central Park, New York.

"I find it invaluable in adding up long columns of figures, and can safely say that I can do twice as much work with the machine."—F. W. SOULS, Registry Clerk, North Chicago Street Railway Co.

"Have found it a great help for accurate and rapid work in multiplication."—W. H. HITT, Chicago Copper Refining Co.

"It is a great relief from the irksomeness of meteorological computations, and adds decidedly to their accuracy."—M. W. HARRINGTON.

"This bank purchased a Comptometer of the Felt & Tarrant Mfg. Co., and have used it for the past year in the work of adding long columns of figures. It has proved a valuable help, and we would not like to be without it."—W. A. SHAW, Cashier Merchants' and Manufacturers' National Bank, Pittsburgh, Pa.

Send for circular.

FELT & TARRANT MFG. CO., 52 Illinois St., Chicago.